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**Moeller et al.**

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(54) **NETWORKED SOUND MASKING SYSTEM**

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(73) Assignee: **777388 Ontario Limited**, Ontario (CA)

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This patent is subject to a terminal disclaimer.

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(51) **Int. Cl.**
***H04R 3/02*** (2006.01)

(52) **U.S. Cl.**
USPC ..... **381/73.1**; 700/94

(58) **Field of Classification Search**
USPC ..... 381/104–109, 73.1, 97–100, 101, 381/102–103, 71.1–71.3, 94.1–94.3, 57; 700/94; 709/251–253
See application file for complete search history.

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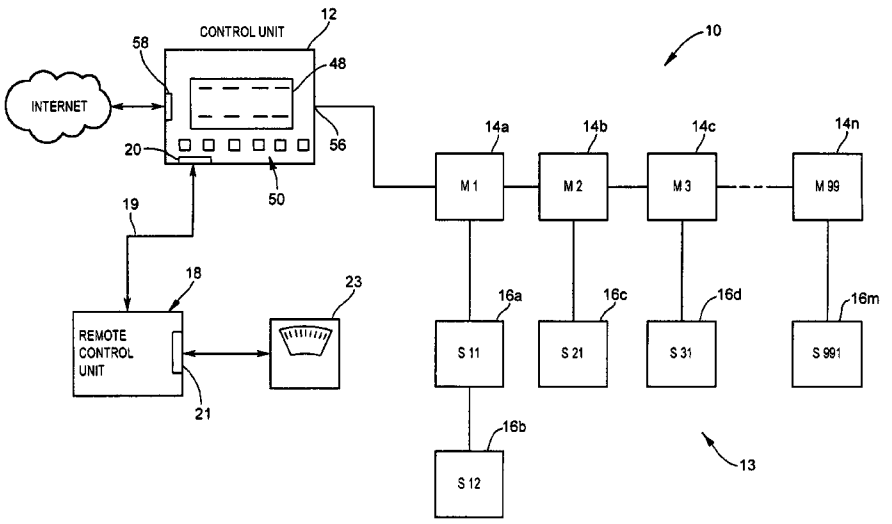
(57) **ABSTRACT**

A sound masking system for shaping the ambient noise level in a physical environment. The sound masking system comprises a networked and distributed system having a number of master units coupled together and to a control unit. One or more of the master units may include satellite sound masking units which function to reproduce the sound masking signal generated by the master sound masking unit. Each of the master units is addressable over the network by the control unit enabling the control unit to program the contour, spectral band, and gain characteristics of the sound masking output signal. The system may also include a remote control unit which provides the capability to tune and adjust each master sound masking unit in situ without requiring physical access through the ceiling installation.

**26 Claims, 15 Drawing Sheets**



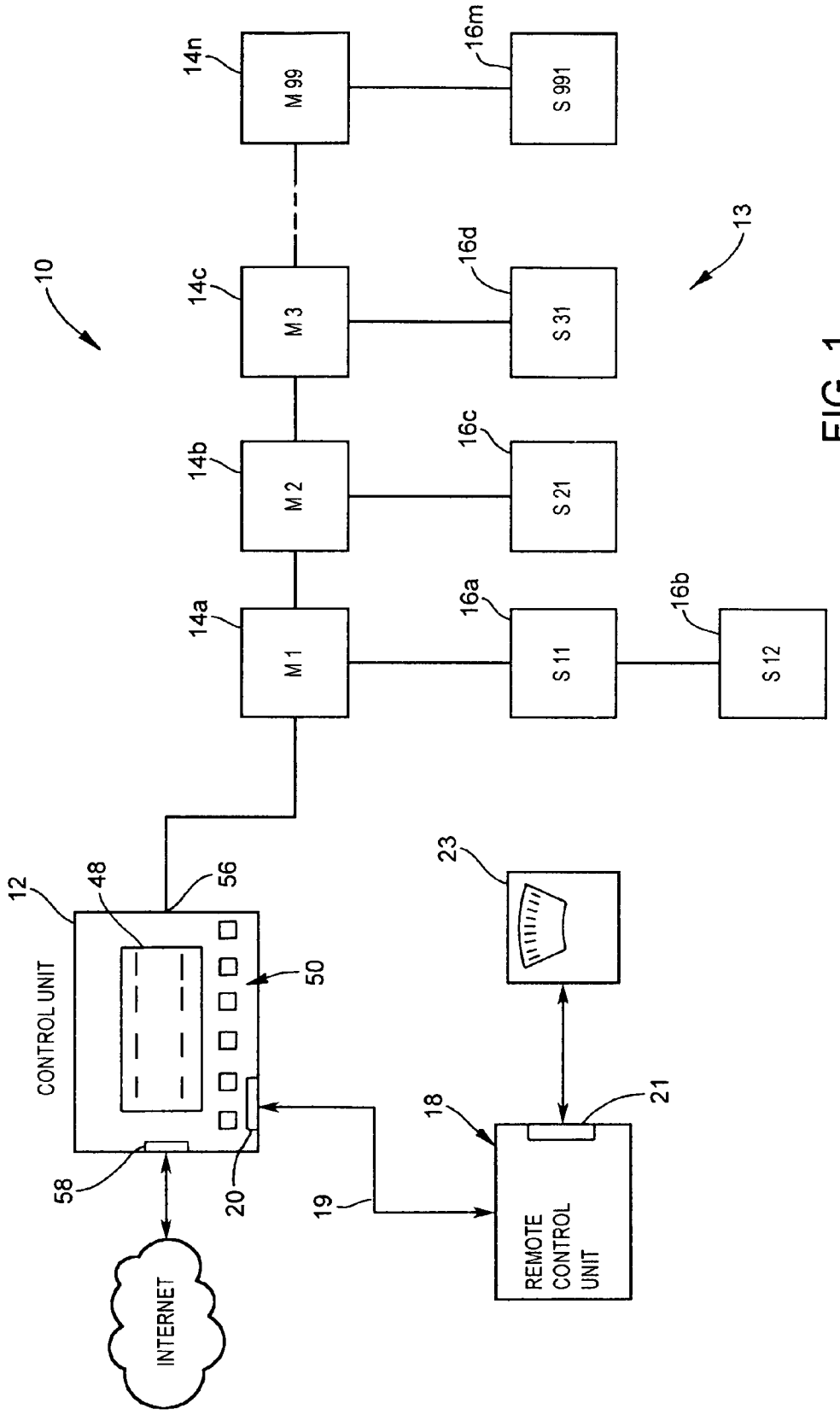

10
13
14n
M 99
16m
S 991
14c
M 3
16d
S 31
14b
M 2
16c
S 21
14a
M 1
16a
S 11
16b
S 12
12
48
56
CONTROL UNIT
50
58
20
19
23
18
21
REMOTE CONTROL UNIT
INTERNET

FIG. 1

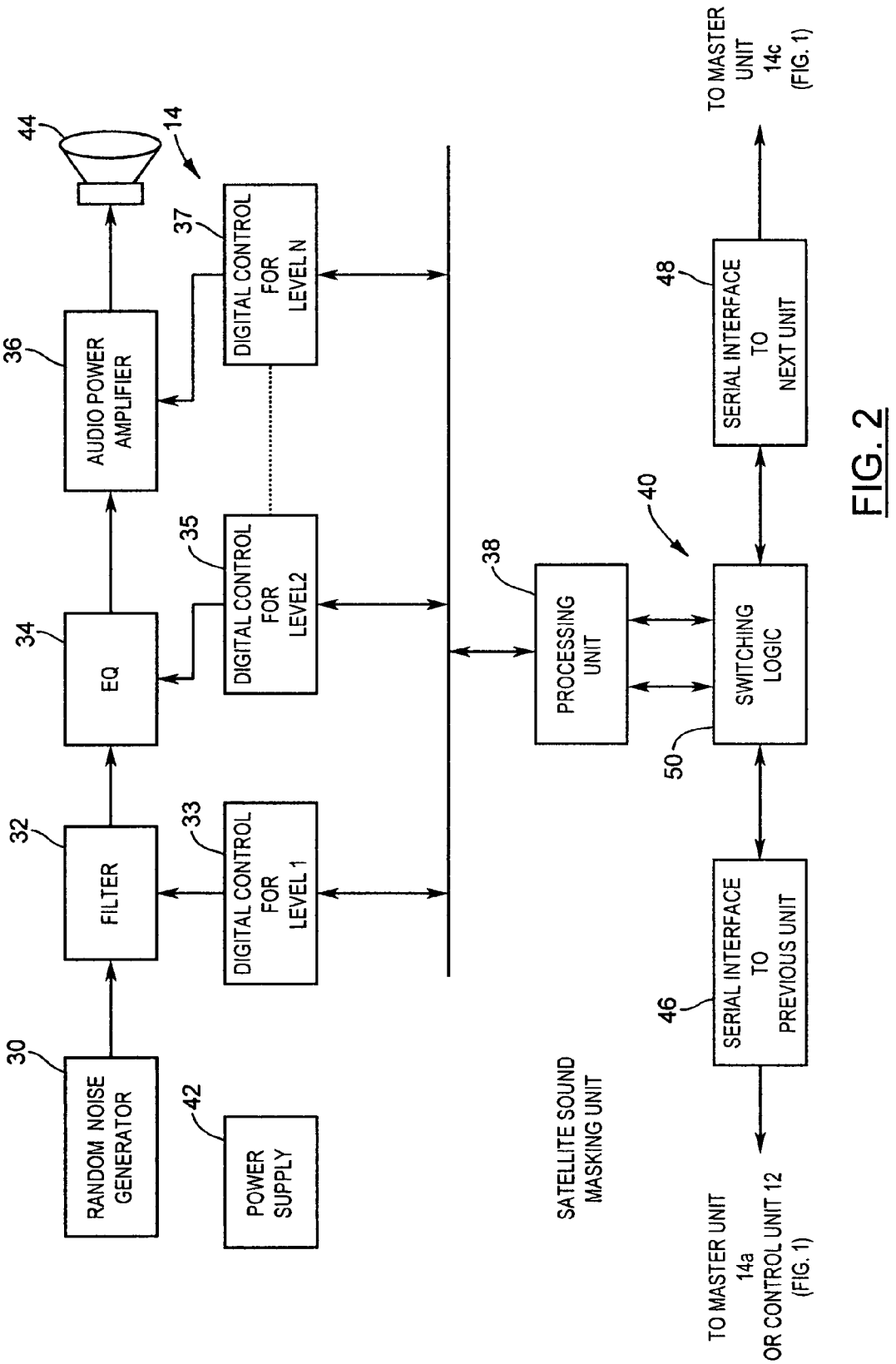

RANDOM NOISE GENERATOR
30
FILTER
32
EQ
34
AUDIO POWER AMPLIFIER
36
DIGITAL CONTROL FOR LEVEL 1
33
DIGITAL CONTROL FOR LEVEL2
35
DIGITAL CONTROL FOR LEVEL N
37
14
44
POWER SUPPLY
42
PROCESSING UNIT
38
SWITCHING LOGIC
40
50
SERIAL INTERFACE TO PREVIOUS UNIT
46
SERIAL INTERFACE TO NEXT UNIT
48
TO MASTER UNIT 14a OR CONTROL UNIT 12 (FIG. 1)
TO MASTER UNIT 14c (FIG. 1)
SATELLITE SOUND MASKING UNIT

FIG. 2

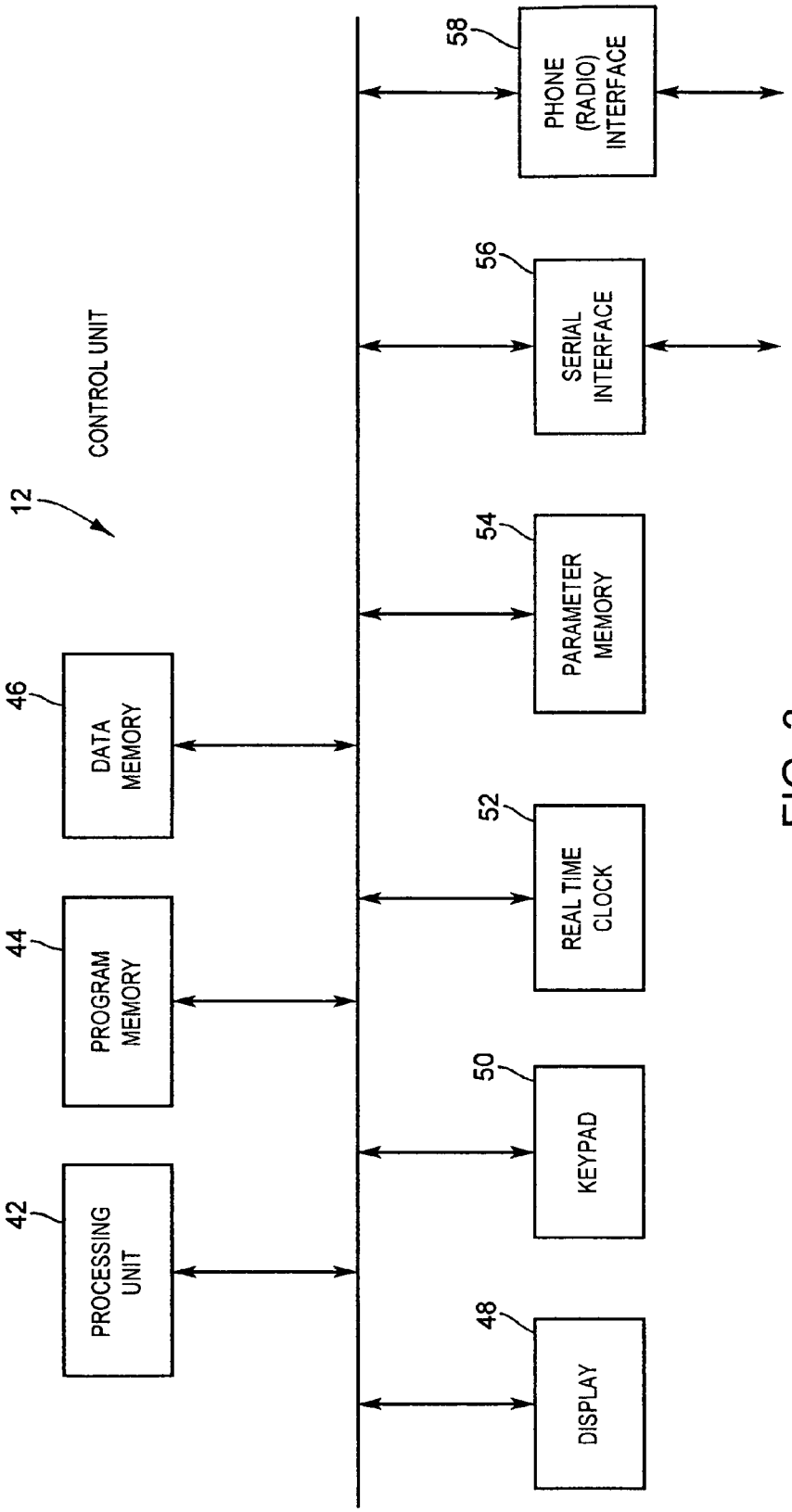

CONTROL UNIT
12
PROCESSING UNIT
42
PROGRAM MEMORY
44
DATA MEMORY
46
DISPLAY
48
KEYPAD
50
REAL TIME CLOCK
52
PARAMETER MEMORY
54
SERIAL INTERFACE
56
PHONE (RADIO) INTERFACE
58

FIG. 3

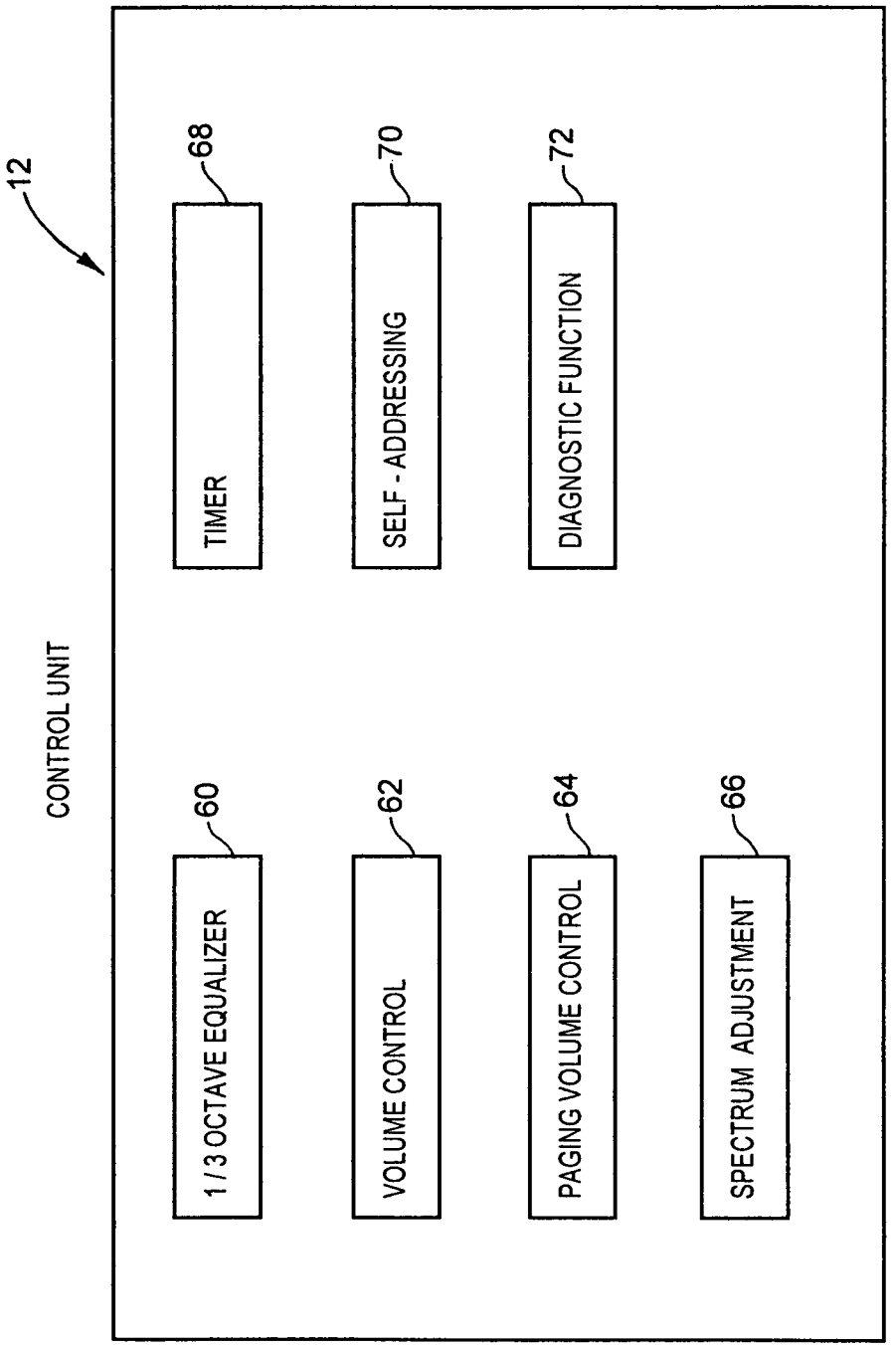

12
CONTROL UNIT
68
TIMER
70
SELF - ADDRESSING
72
DIAGNOSTIC FUNCTION
60
1 / 3 OCTAVE EQUALIZER
62
VOLUME CONTROL
64
PAGING VOLUME CONTROL
66
SPECTRUM ADJUSTMENT

FIG. 4

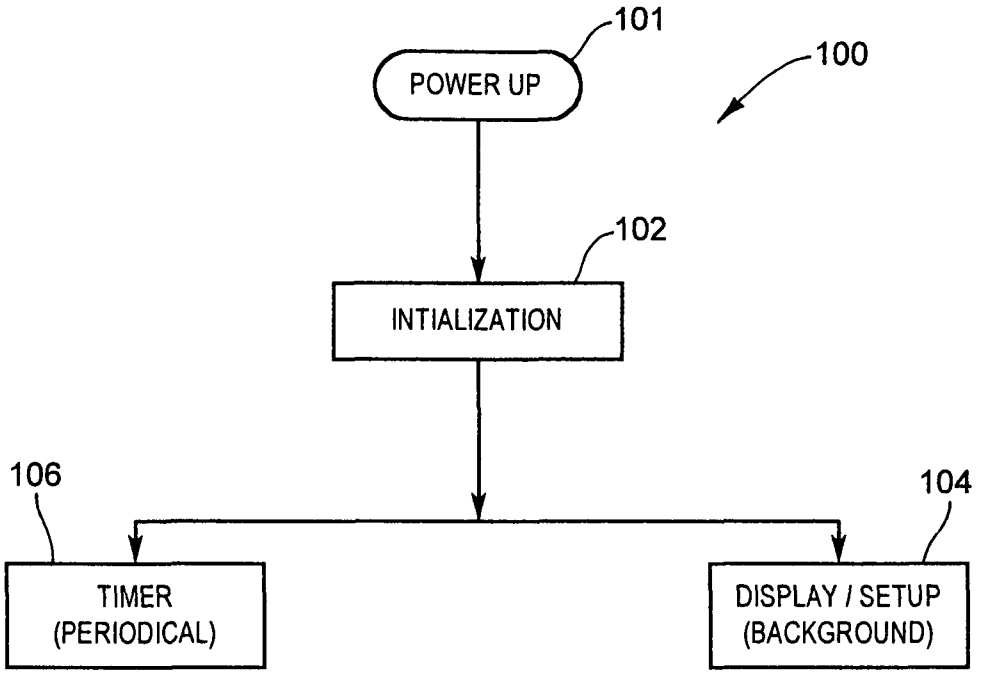

101
100
POWER UP
102
INTIALIZATION
106
104
TIMER
(PERIODICAL)
DISPLAY / SETUP
(BACKGROUND)

FIG. 5

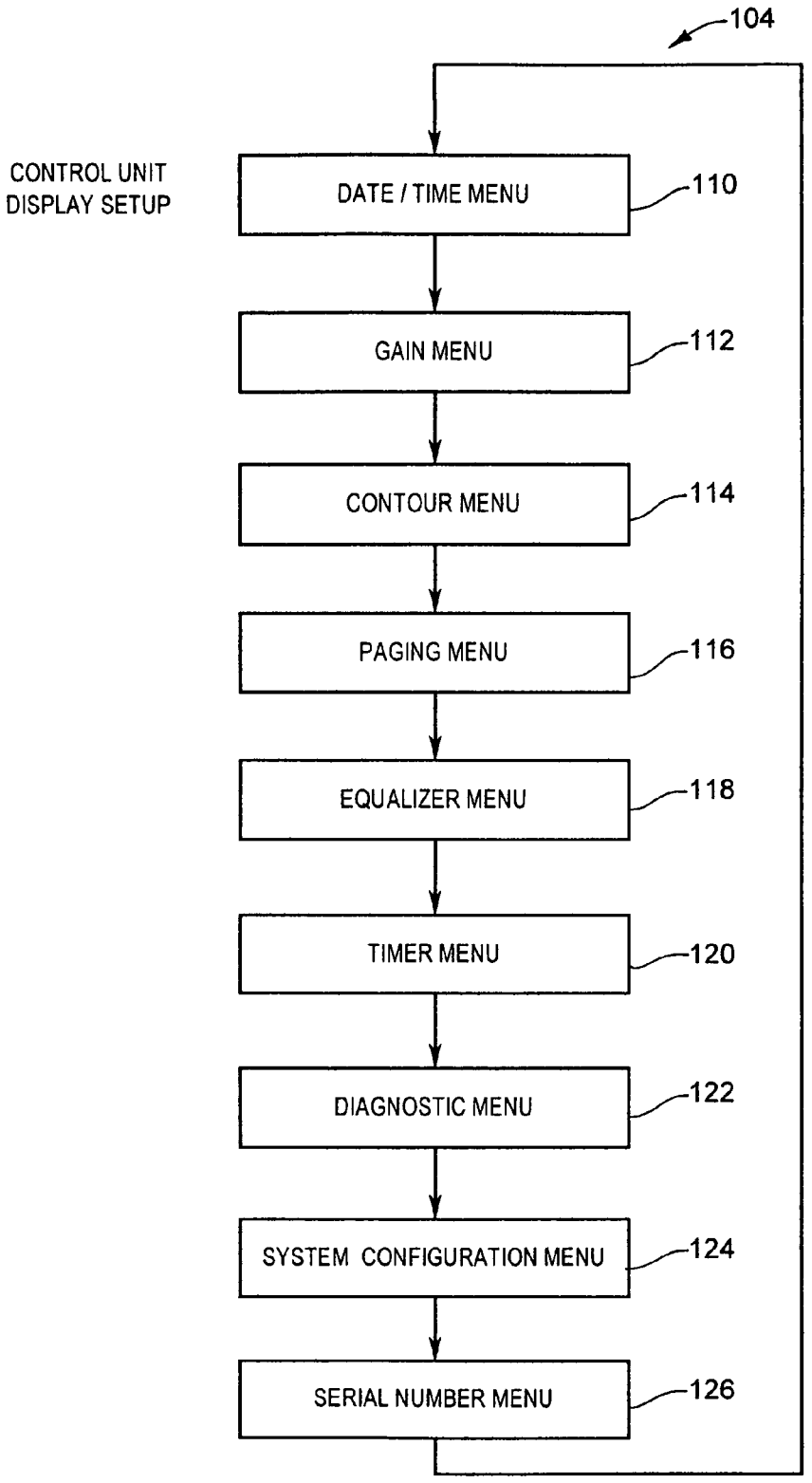

104
CONTROL UNIT
DISPLAY SETUP
DATE / TIME MENU
110
GAIN MENU
112
CONTOUR MENU
114
PAGING MENU
116
EQUALIZER MENU
118
TIMER MENU
120
DIAGNOSTIC MENU
122
SYSTEM CONFIGURATION MENU
124
SERIAL NUMBER MENU
126

FIG. 6

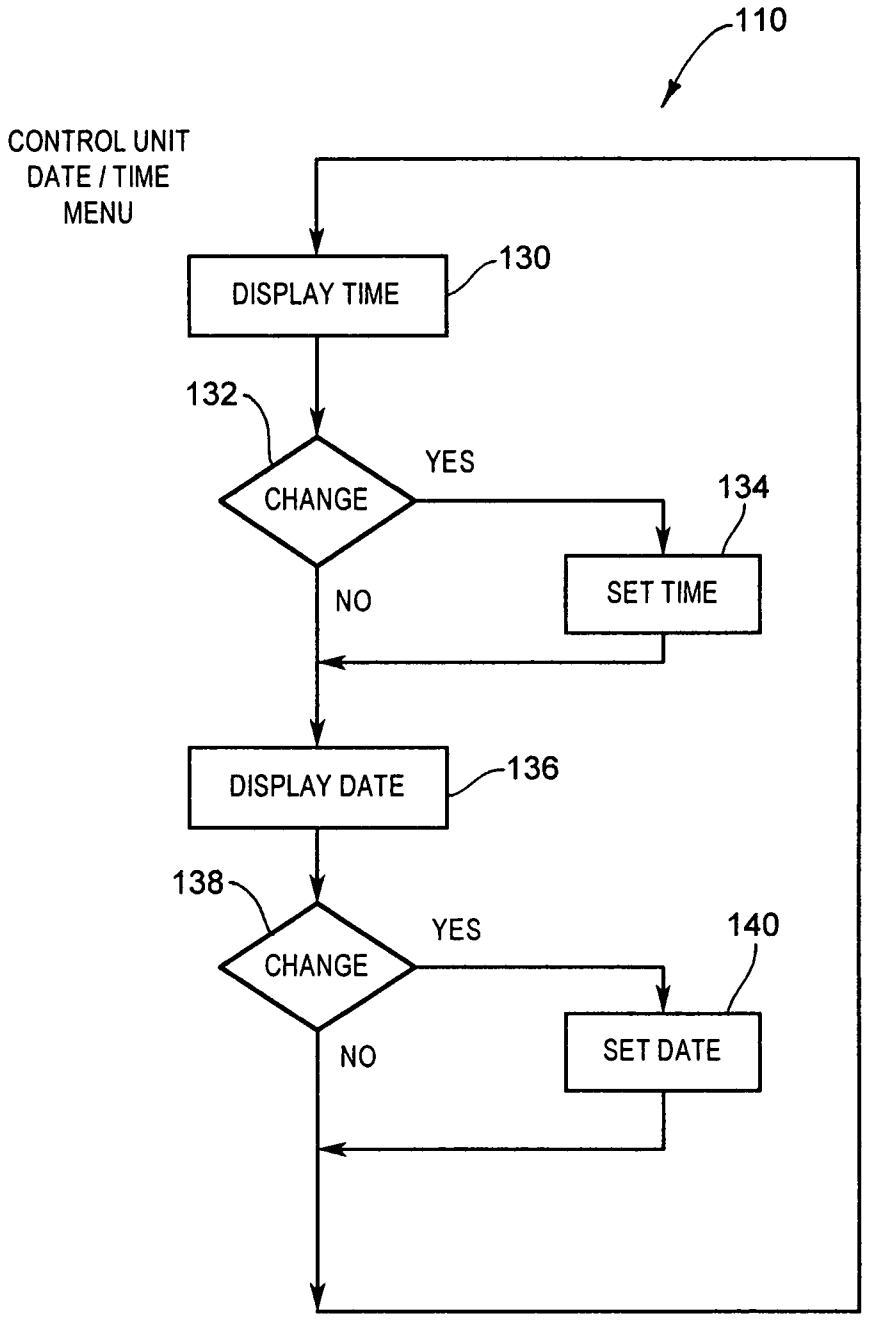

110
CONTROL UNIT
DATE / TIME
MENU
DISPLAY TIME
130
132
CHANGE
YES
134
SET TIME
NO
DISPLAY DATE
136
138
CHANGE
YES
140
SET DATE
NO

FIG. 7

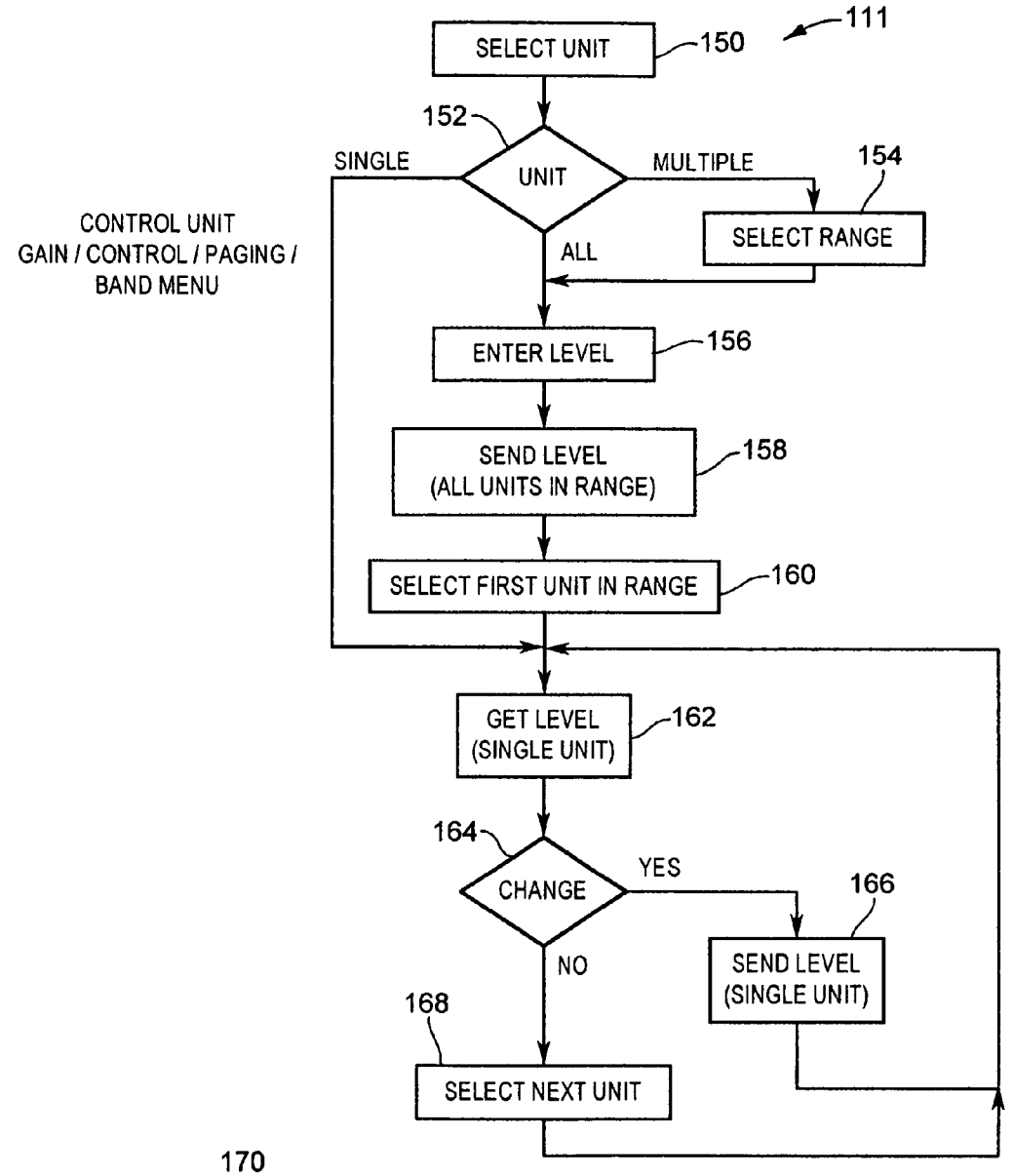

111
SELECT UNIT
150
152
UNIT
SINGLE
MULTIPLE
154
SELECT RANGE
ALL
CONTROL UNIT
GAIN / CONTROL / PAGING /
BAND MENU
ENTER LEVEL
156
SEND LEVEL
(ALL UNITS IN RANGE)
158
SELECT FIRST UNIT IN RANGE
160
GET LEVEL
(SINGLE UNIT)
162
164
CHANGE
YES
166
SEND LEVEL
(SINGLE UNIT)
NO
168
SELECT NEXT UNIT

FIG. 8

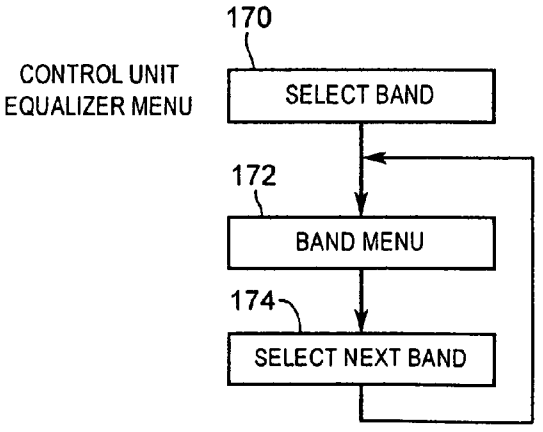

170
CONTROL UNIT
EQUALIZER MENU
SELECT BAND
172
BAND MENU
174
SELECT NEXT BAND

FIG. 9

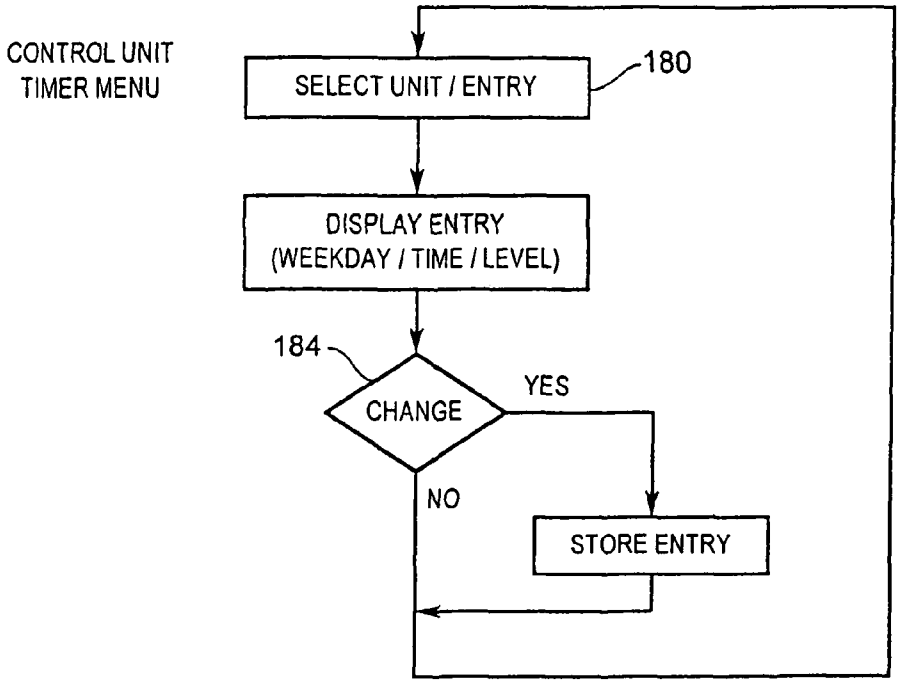

CONTROL UNIT
TIMER MENU
SELECT UNIT / ENTRY
180
DISPLAY ENTRY
(WEEKDAY / TIME / LEVEL)
184
CHANGE
YES
NO
STORE ENTRY

FIG. 10

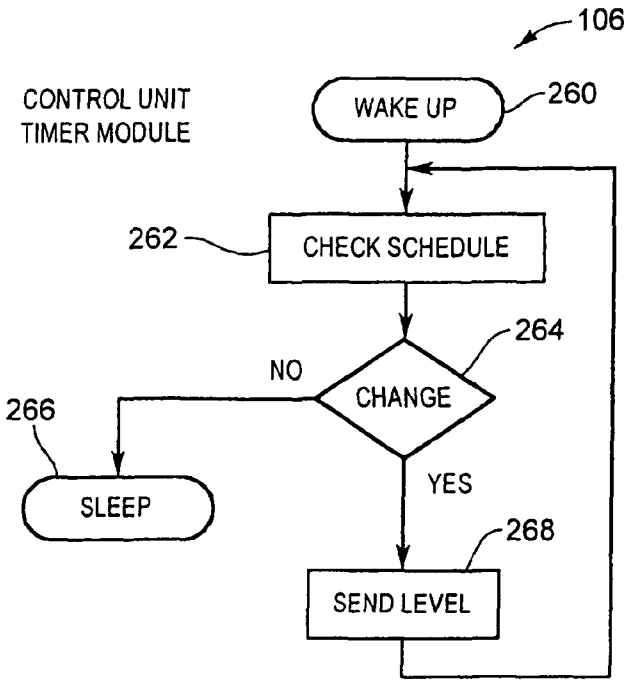

106
CONTROL UNIT
TIMER MODULE
WAKE UP
260
262
CHECK SCHEDULE
264
NO
CHANGE
266
SLEEP
YES
268
SEND LEVEL

FIG. 13

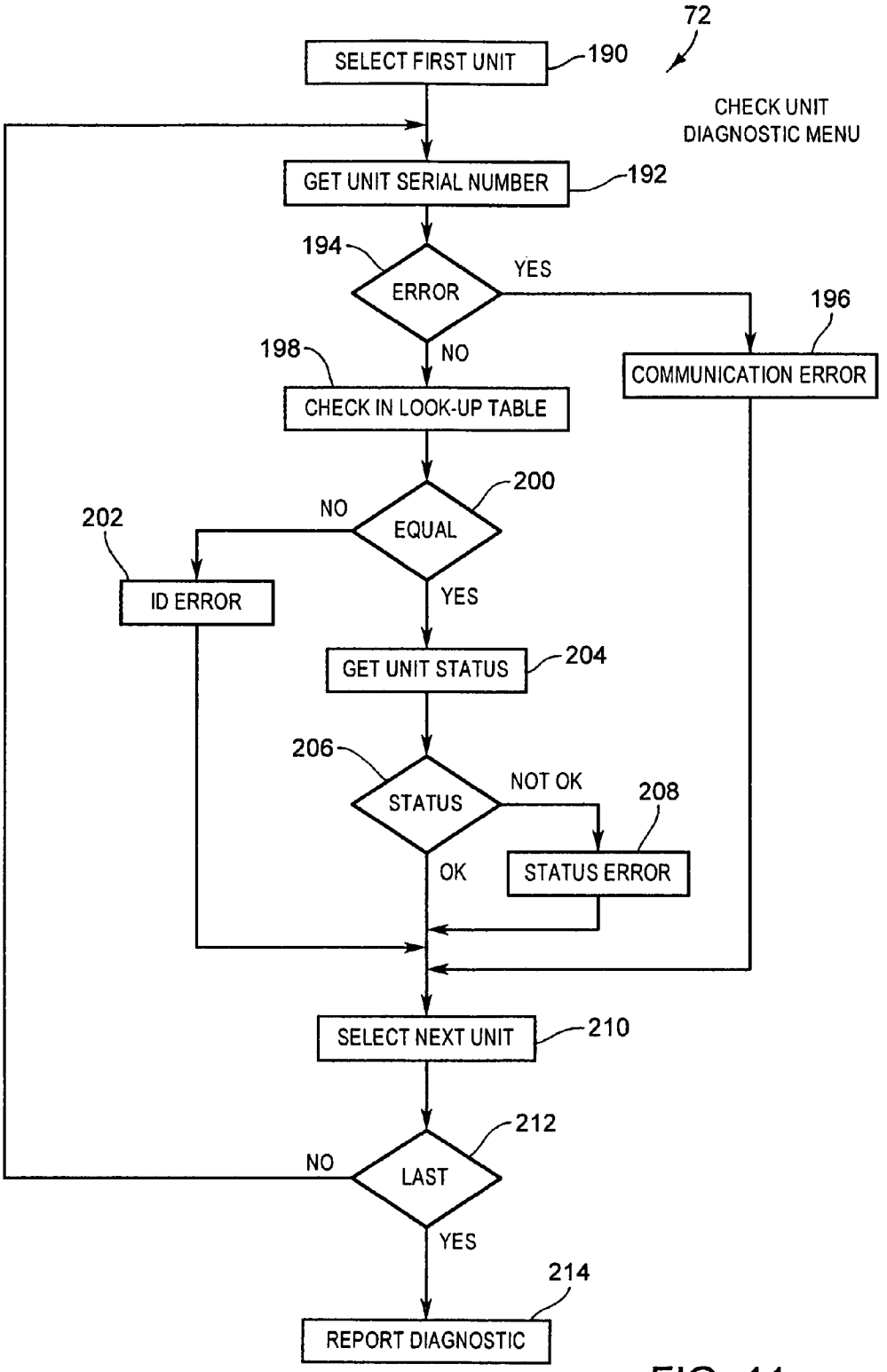

72
SELECT FIRST UNIT
190
CHECK UNIT DIAGNOSTIC MENU
GET UNIT SERIAL NUMBER
192
194
ERROR
YES
196
NO
198
COMMUNICATION ERROR
CHECK IN LOOK-UP TABLE
200
NO
EQUAL
202
ID ERROR
YES
GET UNIT STATUS
204
206
STATUS
NOT OK
208
OK
STATUS ERROR
SELECT NEXT UNIT
210
212
NO
LAST
YES
214
REPORT DIAGNOSTIC

FIG. 11

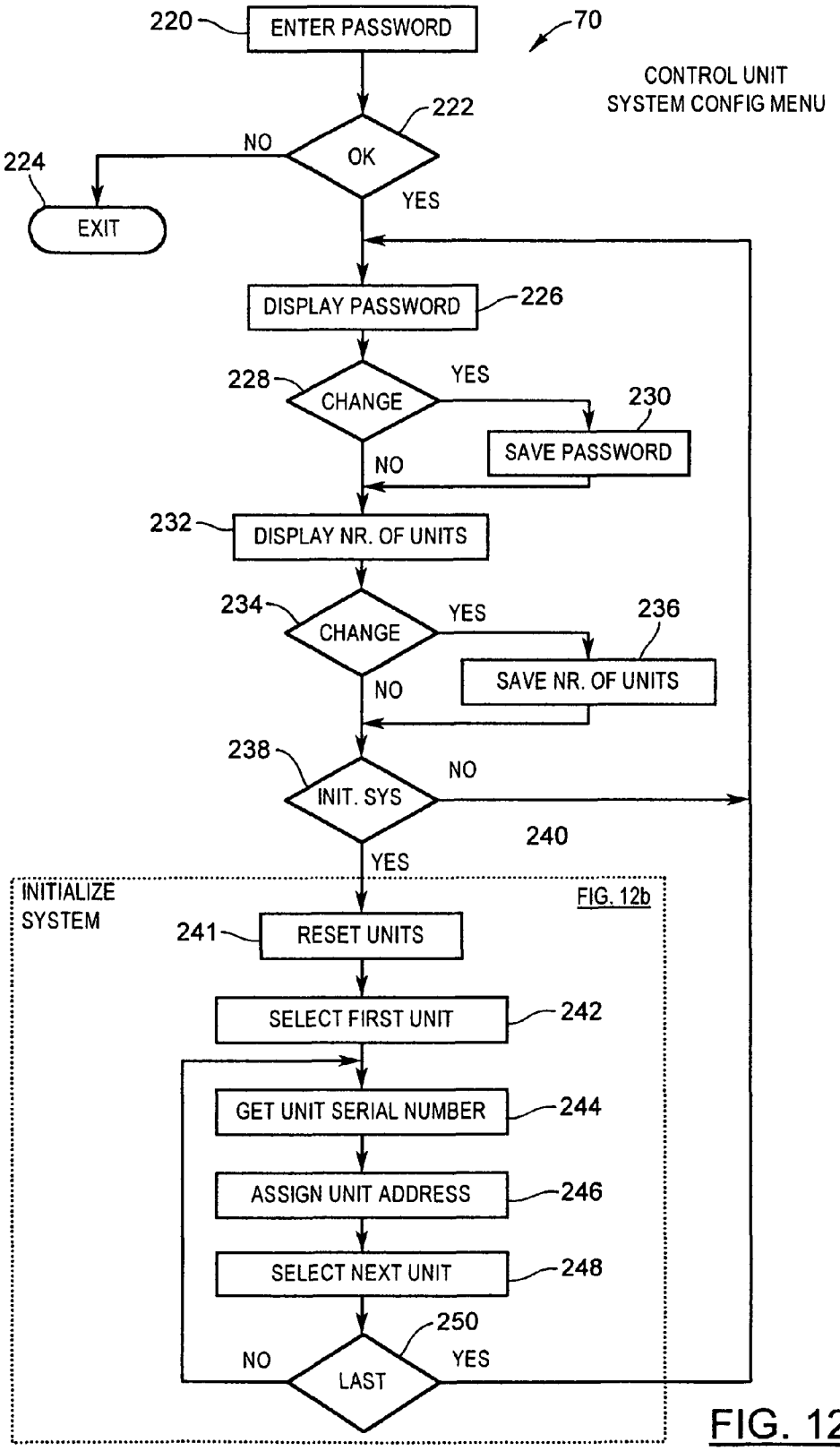

220
ENTER PASSWORD
70
CONTROL UNIT
SYSTEM CONFIG MENU
222
NO
OK
224
YES
EXIT
DISPLAY PASSWORD
226
228
CHANGE
YES
230
SAVE PASSWORD
NO
232
DISPLAY NR. OF UNITS
234
CHANGE
YES
236
SAVE NR. OF UNITS
NO
238
INIT. SYS
NO
240
YES
INITIALIZE
SYSTEM
FIG. 12b
241
RESET UNITS
SELECT FIRST UNIT
242
GET UNIT SERIAL NUMBER
244
ASSIGN UNIT ADDRESS
246
SELECT NEXT UNIT
248
250
NO
LAST
YES

FIG. 12a

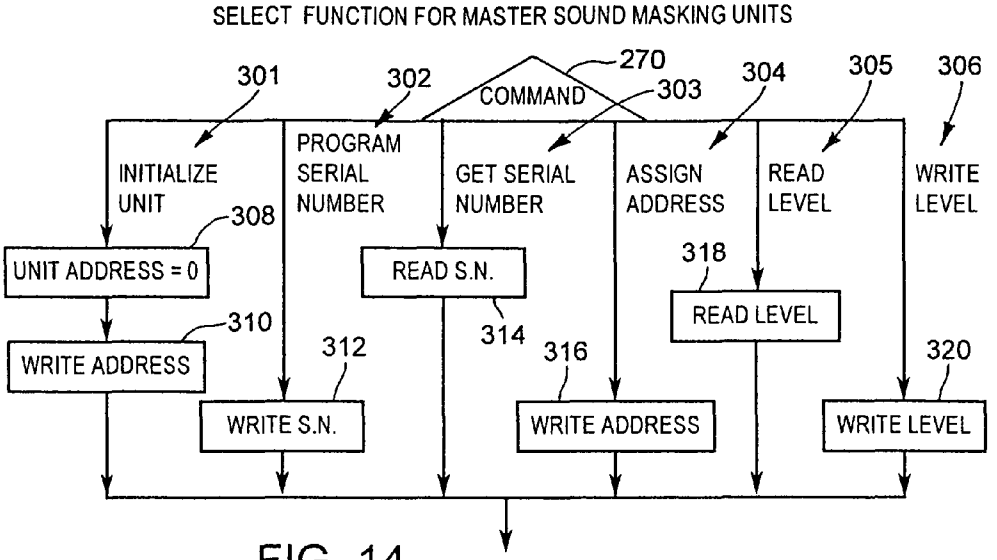



FIG. 14

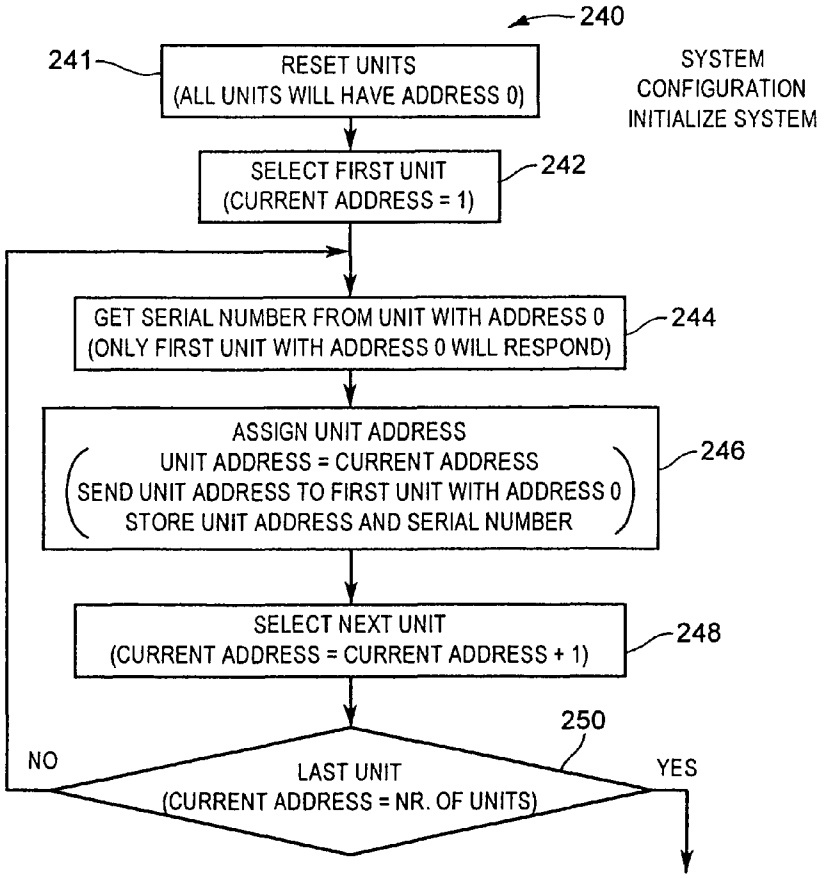



FIG. 12b

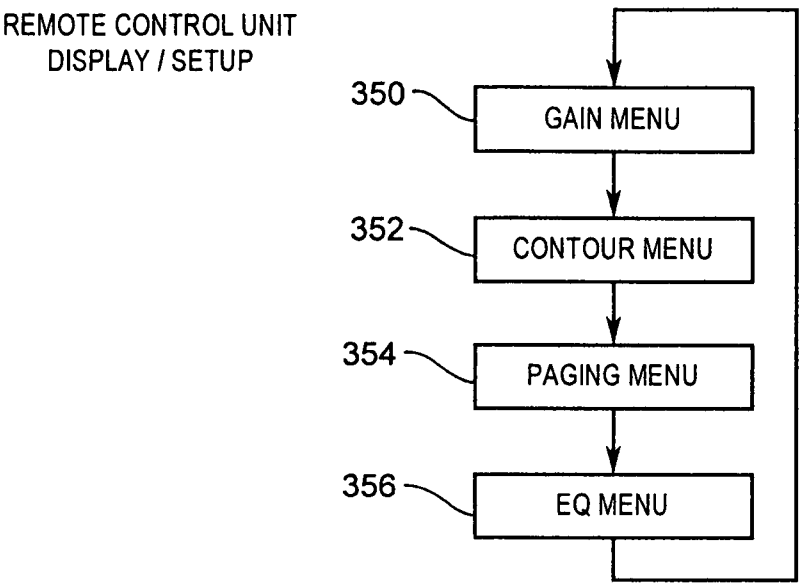

REMOTE CONTROL UNIT
DISPLAY / SETUP
350
GAIN MENU
352
CONTOUR MENU
354
PAGING MENU
356
EQ MENU

FIG. 15

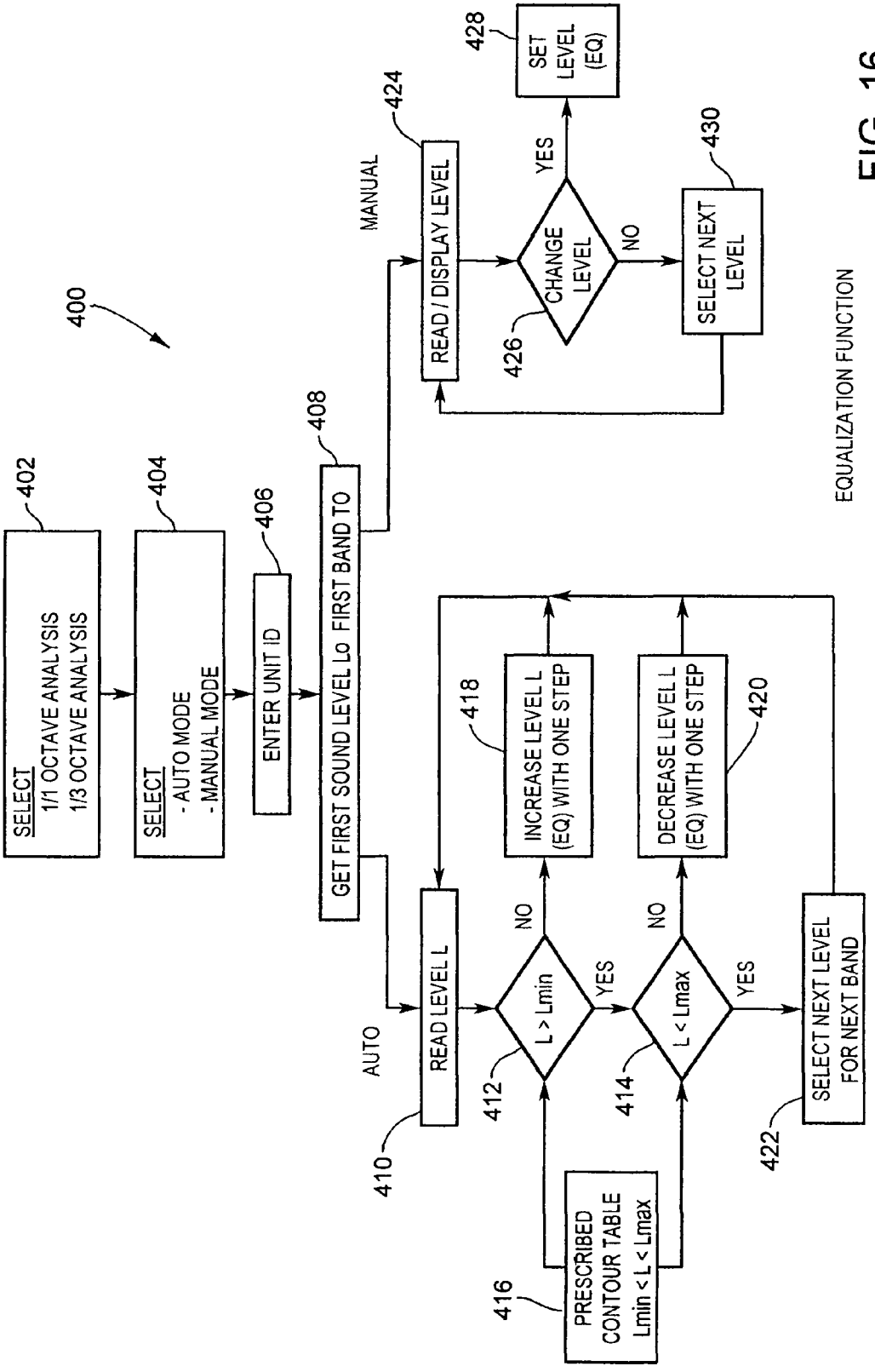



FIG. 16

EQUALIZATION FUNCTION

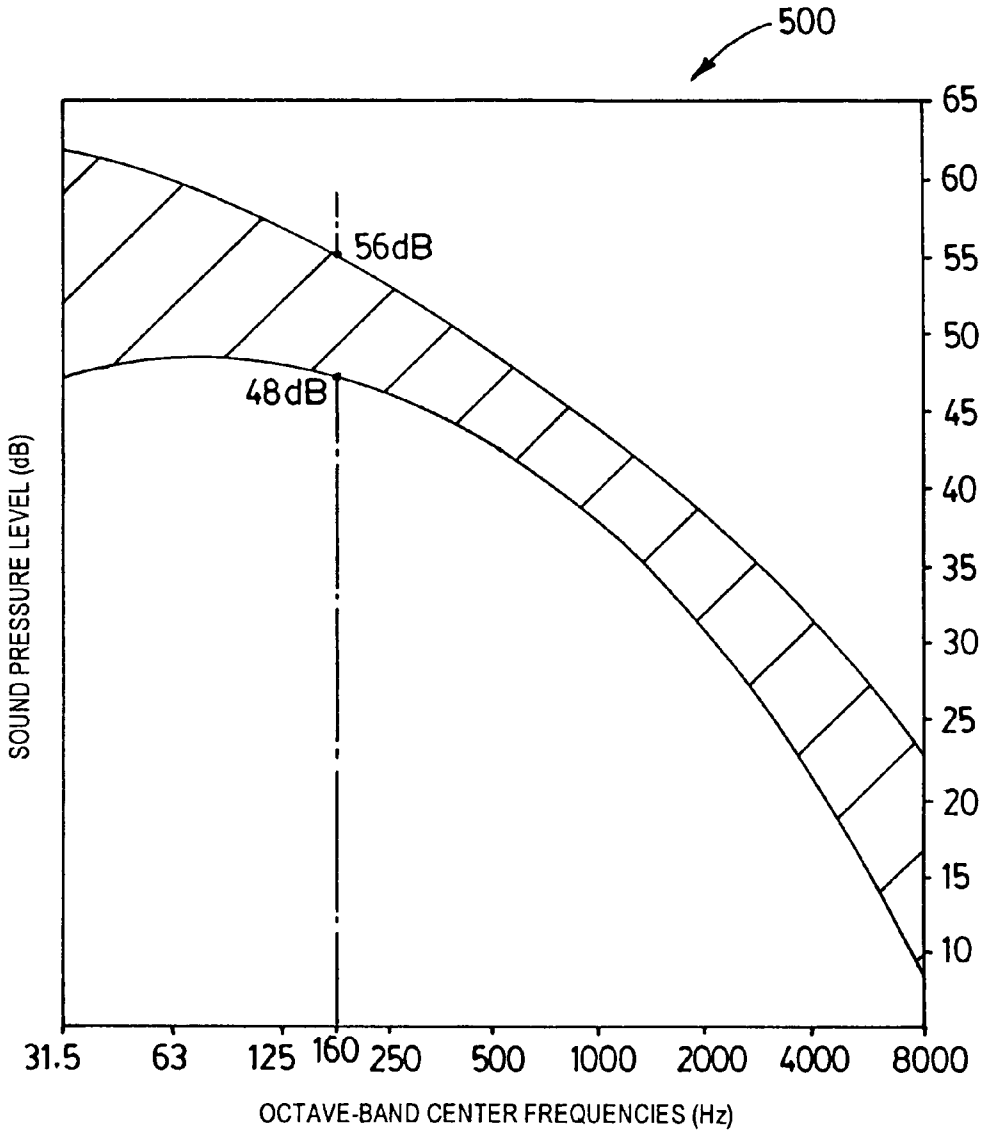

500
56dB
48dB
SOUND PRESSURE LEVEL (dB)
65
60
55
50
45
40
35
30
25
20
15
10
31.5
63
125
160
250
500
1000
2000
4000
8000
OCTAVE-BAND CENTER FREQUENCIES (Hz)

FIG. 17

# NETWORKED SOUND MASKING SYSTEM

## FIELD OF THE INVENTION

The present invention relates to sound masking, and more particularly to a networked and remote controllable sound masking system.

## BACKGROUND OF THE INVENTION

Sound masking systems are widely used in offices and similar workplaces where an insufficient level of background sound results in diminished speech privacy. Such environments suffer from a high level of noise distractions, and lower comfort levels from an acoustic perspective. Sound masking systems operate on the principle of masking which involves generating a background sound in a given area. The background sound has the effect of limiting the ability to hear two sounds of similar sound pressure level and frequency simultaneously. By generating and distributing the background noise in the given area, the sound masking system masks or covers the propagation of other sounds in the area and thereby increases speech privacy, reduces the intrusion of unwanted noise, and improves the general acoustic comfort level in the area or space.

Sound masking systems are of two main types: centrally deployed systems and independent self-contained systems. In a centrally deployed system, a central noise generating source supplies a series of loudspeakers installed throughout the physical area or space to be covered. The independent self-contained system comprises a number of individual self-contained sound masking units which are installed in the physical space. The sound masking units operate independently of each other, but may include a number of satellite speakers which extend the range of each self-contained, i.e. master, sound masking unit. Most sound masking systems include the capability for broadcast announcements and music over the loudspeakers contained in the sound masking units.

The primary goal of sound masking systems is to provide an unobtrusive, effective masking sound that is adjustable for maximum consistency, and offers the ability to meet the requirements of the occupants. The masking output is preferably sufficient to accommodate the existing acoustic requirements of the workplace environment and adjustable to handle changes to the acoustic characteristics of environment which occur over time. Similar demands are placed on the system for the public address and music functions. In short, the preferred sound masking system would produce an output with a frequency and volume level that is controllable to produce the desired acoustic response for workplace zones ranging in size from the smallest to larger spaces.

Centralized systems are characterized by achieving uniformity of output, but not uniformity of acoustic response for the space. In a centralized system, the frequency spectrum of the sound masking output can only be adjusted at a centrally located equalizer, and as a result the sound masking output has the same frequency spectrum for all of the loudspeakers. Depending on the configuration of the centralized system, volume adjustments may be made for very large physical spaces, i.e. zones, by adjusting the amplifier output; for relatively smaller zones, volume adjustments are made by changing wiring connections or controls on the speaker enclosure, or by adjusting a hardwired zone volume control. In practice, it is difficult to accommodate environmental acoustic variations using a centralized system because the volume and frequency spectrum adjustments required for the typical physical zone size are too large to achieve a uniform acoustic result. A further disadvantage is that many of the adjustments for a centralized sound masking system require an installer or technician to re-enter the ceiling space or to rewire the speakers in the system.



The independent self-contained system has a number of important advantages over the centralized arrangement. The independent self-contained system is more effective in terms of sound generation, volume adjustment, and frequency adjustment which, in turn, improves the performance of such systems as compared to centralized systems. In particular, the independent self-contained system provides a defined non-frequency specific output range for the masking output spectrum, and adjustments can be made at each master sound masking unit. The volume controls for an independent self-contained system also provide more flexibility than in the centralized system, and provide for finer adjustments in smaller zones, in addition to centralized volume controls for large zone or global adjustment. However, with existing systems it is still necessary to re-enter the ceiling to adjust the frequency spectrum and volume output level for each master sound masking unit, and the controls for providing multi-unit volume zone adjustments require the hardwiring of the units.

While existing independent self-contained systems are more flexible than centralized systems in many regards, they do not satisfy all the requirements of an ideal sound masking system as discussed above. Furthermore, other shortcomings are associated with existing sound masking systems. In both centralized and independent self-contained systems, the public address and music volume controls are limited in the same manner as described above for sound masking output volume controls. Second, any centrally located controls only affect the output level for the speakers or sound masking units which have a hardwired connection. It will be appreciated that this severely limits the adjustability of the system to future changes in the acoustic environment unless at least some of the system is rewired. Third, the tuning procedure for existing systems is time consuming and can still be inaccurate over the system even when undertaken with the appropriate level of skill and attention. And fourthly, adjustments to existing systems must be made on-site.

Accordingly, there remains a need fora networked sound masking system with individually controllable and programmable sound masking units, and which system is easily adaptable to changing sound qualities in a physical space or spaces in a building environment.

## BRIEF SUMMARY OF THE INVENTION

The present invention provides a networked sound masking system with individually controllable and programmable sound masking units.

In a first aspect, the present invention provides a sound masking system for controlling the ambient noise level in a physical environment, the sound masking system comprises: (a) a communication network spanning at least a portion of the physical environment; (b) a plurality of sound masking units, some of the sound masking units include a sound masking component for generating a sound masking output signal and some of the sound masking units include a communication interface for coupling the sound masking units to the communication network for receiving control signals over the communication network; (c) a control unit having a communication interface for coupling to the communication network for transmitting control signals over the communication net-

work to the sound masking units, and the control signals include signals for controlling the operation of at least some of the sound masking units.

In another aspect, the present invention provides a sound masking system for shaping the ambient noise level in a physical environment, the sound masking system comprises: (a) a communication network spanning at least a portion of the physical environment; (b) a plurality of sound masking units, some of the sound masking units include a sound masking circuit for generating a sound masking output signal for shaping the ambient noise level in the vicinity of each of the sound masking units, a programmable controller and at least one digital component for controlling operation of the sound masking circuit, and a communication interface for coupling the sound masking units to the communication network, and the programmable controller being coupled to the communication network for receiving control signals from the communication network for altering the operation of the sound masking circuit; (c) a control unit, the control unit having a communication interface for coupling the control unit to the communication network for transmitting control signals over the communication network to the sound masking units, and the control signals include signals for controlling the operation of at least some of the sound masking units; (d) wherein the sound masking circuit comprises a random noise generating component for generating an incoherent signal output, a filter component for receiving the incoherent signal output and generating an incoherent signal output with a predetermined contour, and an output amplifier for amplifying the contoured incoherent signal output, and the digital component comprising a digital potentiometer coupled to the filter component for altering the contour of the incoherent signal output in response to control signals from the programmable controller.

In a further aspect, the present invention provides in a networked sound masking system for controlling ambient noise level in a physical environment, the networked sound masking system having a communication network for coupling a plurality of sound masking units, the sound masking units span the physical environment, the sound masking units include a sound masking component for generating a sound masking output signal and include a communication interface to the communication network for receiving control signals over the communication network, and a control unit having a communication interface for coupling the control unit to the communication network for transmitting control signals to the sound masking units, and the control signals include signals for selectively controlling the operation of the sound masking units, a remote control unit for generating adjustment signals for the control unit for adjusting characteristics of the sound masking signal output produced by the sound masking units, the remote control unit comprises: (a) a remote communication interface for transmitting the adjustment signals to the control unit, and the control unit has an external communication interface compatible with the remote communication interface; (b) an input component for receiving sound level readings for the physical environment; (c) a component responsive to the sound level readings for generating the adjustment signals associated with the characteristics of the sound masking output signal for the sound masking units.

Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

## BRIEF DESCRIPTION OF THE DRAWINGS

Reference will now be made to the accompanying drawings, which show, by way of example, a preferred embodiment of the present invention, and in which:

FIG. **1** shows in block diagram form a networked sound masking system according to the present invention;

FIG. **2** shows a sound masking unit in block diagram form for the networked sound masking system of FIG. **1**;

FIG. **3** shows in block diagram form a control unit for the networked sound masking system of FIG. **1**;

FIG. **4** shows the control unit of FIG. **3** in more detail, and in particular the functional modules for the control unit;

FIG. **5** shows in flowchart form a main functional processing method for the control unit of FIG. **3**;

FIG. **6** shows in flowchart form the processing steps for the display/setup function in the control unit for the networked sound masking system according to the present invention;

FIG. **7** shows in flowchart form the processing steps for the timer function in the control unit for the networked sound masking system;

FIG. **8** shows in flowchart form the processing steps for the gain/contour/paging/band setting functions in the control unit for the networked sound masking system;

FIG. **9** shows in flowchart form the processing steps for the equalizer function in the control unit for the networked sound masking system;

FIG. **10** shows in flowchart form the steps for setting the timer function for the control unit;

FIG. **11** shows in flowchart form the processing steps for a diagnostics function in the control unit for the networked sound masking system;

FIG. **12**(*a*) shows in flowchart form the steps for a system configuration function in the control unit for the networked sound masking system;

FIG. **12**(*b*) shows in flowchart form the steps for configuring addresses for the sound masking units according to an aspect of the present invention;

FIG. **13** shows in flowchart form the processing steps for the timer function for the control unit;

FIG. **14** shows in flowchart form functions for controlling the sound masking units in the networked sound masking system according to the present invention;

FIG. **15** shows in flowchart form functions implemented for the remote control unit in the networked sound masking system according to the present invention;

FIG. **16** shows in flowchart form the processing steps for an equalization function in the networked sound masking system according to the present invention; and

FIG. **17** shows in graphical form a Prescribed Spectrum Contour table for the sound masking signal.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference is first made to FIG. **1**, which shows in block diagram form a networked sound masking system according to the present invention and indicated by reference **10**.

As shown in FIG. **1**, the networked sound masking system **10** comprises a control unit **12**, and a network **13** comprising a plurality of master sound masking units **14**, indicated individually by **14***a*, **14***b*, **14***c* . . . **14***n*, and one or more satellite sound masking units **16**, indicated individually by **16***a*, **16***b*, **16***c*, **16***d*, . . . **16***m*. The physical connections for the network **13** between the master sound masking units **14** may comprise 5, 4 or 3 conductors. In a 5 conductor arrangement, two

conductors carry power, two conductors provide a communication channel, and one conductor provides for paging.

The master sound masking unit **14** and the satellite sound masking units **16** provide the sound masking functionality, i.e. sound masking and signal generation and amplification. Each sound masking group, i.e. master sound masking unit **14** together with the associated satellite sound masking units **16**, is configured for a particular physical spaces, e.g. office, room, zone in a open office, etc. The master sound masking units **14** are configured to generate a specific sound masking signal at a specified output level for performing the sound masking in the physical space. As will be described in more detail below, the sound masking signal is generated according to programmable spectrum, equalizer, and volume settings. The satellite sound masking units **16** are connected to their associated master unit **14** and comprise a speaker which reproduces the sound masking signal generated by the master unit **14**. The satellite units **16** provide a cost-effective way to expand the coverage of the master sound masking unit **14** in a building space.

The control unit **12** as will be described in more detail couples to the network **13** and provides the capability to adjust the functional aspects of the master sound masking units **14** and the satellite sound masking units **16**. The sound masking functions include masking signal spectrum, masking signal output volume, and paging volume. The control unit **12** also provides diagnostic functions and timer control functions. The control unit **12** may also include testing functions, such as a test function which compares existing sound measurements to the desired sound parameters for the space and calculates the adjustments to be made.

The control unit **12** configures the network **13** by assigning identities or addresses to each of the master units **14**. The addressing of the individual master units **14** enables the control unit **12** to direct commands and/or status requests to individual master sound masking units **14** (and the associated satellite sound masking units **16**), or to groups of master sound masking units **14**, or to the entire network **13** as a whole. The control unit **12** is then used to set/adjust the masking signal spectrum, the masking signal volume, and/or the paging volume for the selected (i.e. addressed) master and satellite sound masking units **14** and **16**. According to another aspect, the master sound masking units **14** may include a digital equalizer for providing greater programming flexibility over the spectrum for the sound masking signal generated by the selected master and satellite sound masking units **14** and **16**.

As also shown in FIG. **1**, the system **10** may include a remote control unit **18**. The remote control unit **18** works in conjunction with the control unit **12** to display and/or change the current adjustment settings (i.e. spectrum adjustment settings, equalizer settings, masking signal volume level, and paging volume) for the master units **14**. As described below, the remote control unit **18** can accept as input sound measurements taken by a sound level meter, or another configuration the remote control unit **14** allows a user to measurements of the acoustical environment for the building space. The remote control unit **18** communicates with the control unit **12** through a communication interface **20**, for example a radio signal channel, indicated by reference **19**.

In addition to the communication channel **19** for the remote control **18**, the control unit **12** may also include another communication interface **58**. The communication interface **58** provides the capability to access the control unit **12** via a remote location, e.g. an offsite location. The communication interface **58** may comprise a telephone communication, radio communication, computer network (e.g. a Local Area Network (LAN) or a Wide Area Network (WAN)), or a connection through the Internet or World Wide Web (WWW). This provides greater flexibility in configuring, adjusting and maintaining the sound masking system **10** from a remote or off-site location.

Reference is next made to FIG. **2** which shows the master sound masking unit **14** in greater detail. As shown in *Fig.* **2**, the master unit **14** comprises a random noise generator stage **30**, a filter stage **32**, an equalizer stage **34**, and an audio power amplifier stage **36**. The operation of the stages **30**, **32**, **34**, **36** is controlled by a microcontroller **38**. As also shown, the master sound masking unit **14** includes a communication interface **40**. The communication interface **40** couples the master unit **14** to the network **13** and provides the capability to communicate with the control unit **12** and other master sound masking units **14***b*, **14***c* in the network **13**. The master unit **14** includes a local power supply **42** for powering the circuitry. The audio power amplifier stage **36** drives a speaker **44** which emits the sound masking signal.

The random noise generator stage **30** is the signal source for generating the sound masking signal. The random noise generator **30** may comprise a multi-stage shift register and an Exclusive-OR gate network as described in U.S. Pat. No. 4,914,706 which issued to the assignee in common with the subject application. Alternatively, the random noise generator module **30** may be implemented in firmware executed in the microcontroller **38**. The random noise generator **30** may also be implemented as an operational amplifier which couples and amplifies the noise produced by a voltage regulator circuit, such as a Zener diode.

The filter stage **32** is coupled to the output of the random noise generator **30**. The filter stage **32** comprises two filters connected to the respective outputs of the last two stages of the shift register (not shown) in the random noise generator **30** as described in U.S. Pat. No. 4,914,706. Each of the filters comprises a resistive-capacitive ladder network, with one of the filters having a higher cut-off frequency than the other filter. Using this arrangement, each of the filters derives a different output signal from the random noise generator **30** with each of the output signals having a different spectral shape within the defined audio frequency range.

In the preferred embodiment, the filter stage **32** is coupled to the microcontroller **38** through a digital control device **33**. The digital control device **33** comprises a potential divider which is connected between the output ends of the filters in the filter stage and under the control of the microcontroller **38** the output contour of the filter stage **32** is programmable. The digital control device **33** is preferably implemented using a digital potentiometer, such as the device available from XICOR Corp., and has a continuously adjustable tap with at least 32 tap positions. The tap positions are selectable by the microcontroller **38**, and by changing the tap positions the spectral shape of the noise signal output from the random noise generator **30** is controllable.

The equalizer stage **34** comprises an one-third Octave equalizer which is used for adjusting the sound spectrum of the noise signal output to the desired contour. In the preferred embodiment, the equalizer comprises **18** adjustable bandpass filter cells for the 1/3 Octave band and **7** adjustable bandpass filter cells for the 1/1 Octave band, and an adder for summing the outputs. Each filter cell is implemented using an operational amplifier or OP Amp, fixed resistors and capacitors as will be within understanding of one skilled in the art. Preferably, each of the filter cells is coupled to the microcontroller **38** through a digital control device **35**, such as a digital potentiometer to provide for the independent adjustment of the cell about a fixed center frequency under the control of the micro-

controller **38**. In the present embodiment, the 1/3 Octave Band frequencies comprise 160, 200, 250, 315, 400, 500, 630, 800, 1000, 1250, 1600, 2000, 2500, 3150, 4000, 5000, 6300 and 8000 Hertz (Hz). The 1/1 Octave Band frequencies comprise 125, 250, 500, 1000, 2000, 4000, and 8000 Hz. Each filter cell is preset to the prescribed contour, e.g. 48 dB<$V_{f1}$<57 dB and 24 step <$DigiPot_1$<30 step. The output from the equalizer stage **34** is a sound masking signal with a controllable contour which is fed to the amplifier power stage **36**.

The audio power stage **36** provides a controllable output level for the contoured sound masking signal. The contoured sound masked signal is amplified by the audio power stage **36** and output to the speaker **44** which emits a sound masking sound into the physical space. The audio power stage **36** also provides an adjustable amplification level for the providing paging announcements, background music or other broadcasts over the speaker. In the preferred embodiment, the output level of the audio power stage **36** is also controllable by the microcontroller **38** through a digital control device **37**. Preferably, the digital control device **37** comprises a digital potentiometer having at least 32 step settings.

Referring still to FIG. **2**, the communication interface **40** comprises a first serial interface **46**, a second serial interface **48**, and a switching logic stage **50**. The communication interface **40** couples the microcontroller **38** to the network **13** and allows the unit **14** to receive and transmit status requests and control commands. The switching logic stage **50** connects the microcontroller **38** to the first and second serial interfaces **46** and **48**. The first serial interface **46** allows the microcontroller **38** to communicate with an upstream device, for example, the master sound masking unit **14***a* or the control unit **12**. The second serial interface **48** allows the microcontroller **38** to communicate with a downstream device, for example, the master sound masking unit **14***c*. In conjunction with the switching logic stage **50**, the microcontroller **38** monitors the serially encoded messages and acts upon messages which are addressed to the specified master sound masking unit **14**. Each of the master sound masking units **14** is assigned an address according to a self-addressing mechanism as will be described in more detail below.

The satellite sound masking units **16** are associated with respective master sound masking units **14**. The satellite sound masking units **16** each include a speaker, and are coupled to one of the master sound masking units **14**. The satellite sound masking units **16** act as slaves or satellites to the master sound masking unit **14** and reproduce the sound masking signal output generated by the associated master sound masking unit **14**.

Reference is next made to FIG. **3**, which shows the control unit **12** in more detail. As shown, the control unit **12** comprises a processor unit (i.e. a microprocessor) **42**, a program memory **44**, a data memory **46**, a display module **48**, a keypad **50**, a real-time clock module **52**, a parameter memory **54**, a serial communication interface **56**, and the communication interface **58**. As shown in FIG. **4**, the control unit **12** includes a functional module **60** to control the 1/3 Octave equalizer **34** (FIG. **2**), a functional module **62** to provide volume control, a functional module **64** to provide paging volume control, a functional module **66** to provide spectrum adjustment control of the contoured sound masking signal, a functional module **68** to provide timer functions for the system **10**, a functional module **70** to provide addressing of the master sound masking units **14** in the network **13**, and a functional module **72** for performing diagnostic functions. The operation of the functional modules in the control unit **12** is now described in more detail with reference to the flowcharts in FIGS. **5** to **17**.

Reference is first made to FIG. **5**, which shows a start-up process **100** for the control unit **12**. The start-up process **100** is executed in response to a power-up **101** or a reset condition. The start-up process **100** comprises an initialization step **102** which includes configuring the control unit **12**. After the initialization step **102**, the control unit **12** runs a display/setup operation **104** as a background loop, and a timer operation **106**. The timer operation **106** is periodically executed, for example, on an interrupt driven basis or as part of a polling loop in the display/setup operation.

Reference is next made to FIG. **6**, which shows the display/setup operation **104** in more detail. As shown the display/setup operation **104** comprises displaying a series of menu functions on the display **48** (FIG. **1**) which are accessed via selections from the keypad **50** (FIG. **1**). As shown in FIG. **6**, the menu functions include a Date/Time function menu **110**, a Gain function menu **112**, a Contour menu function **114**, a Paging Volume function menu **116**, an Equalizer Setting function menu **118**, a Timer function menu function **120**, a Diagnostic function menu **122**, a System Configuration function menu **124**, and Serial Number function menu **126**.

The processing steps for the Date/Time function menu **110** are shown in FIG. **7**. The first step comprises displaying the time **130** and prompting the user to change the time **132**. If the user selects to change the time, then a set time procedure **134** is executed. Otherwise the date is displayed **136**, and the user is prompted to change the date **138**. If the user selects to change the date, a set date procedure **140** is executed.

Reference is next made to FIG. **8**, which shows in more detail the processing steps for setting the Gain function **112**, the Contour Control function **114**, the Paging Volume function **116**, and the Equalizer Band function **118**. The steps for controlling each of these functions is implemented according to the process **111** shown in FIG. **8**. As shown, the first step comprises selecting the master sound masking unit. In decision block **150**, a selection is made between a single master sound masking unit **14** or multiple master sound masking units **14**. If multiple master sound masking units **14** are to be configured, then the next step **154** involves selecting the range for the sound masking units **14**. The sound masking level, i.e. the gain, for the sound masking units **14** in the range is entered in block **156** and transmitted via the network **13** to all the sound masking units **14** in the selected range. After the sound masking level has been sent to the sound masking units **14** in the range, the first sound masking unit **14***a* in the range is selected, i.e. addressed.

Referring still to FIG. **8**, the next step **162** involves reading the sound masking gain level setting for the master sound masking unit **14** which was selected in step **160** or as a result of the branch from decision block **152**. The gain level setting received from the sound masking unit **14** is compared to the desired setting stored in the control unit **12**, and if a change in the sound masking level is needed as determined in decision block **164**, then the desired sound masking gain level setting is sent to the selected master sound masking unit **14** in block **166**. If no change is indicated for the selected master sound masking unit **14**, then the next master sound masking unit **14** in the network **13** is selected, i.e. addressed, and the steps **162** and **164** are repeated. The same processing steps are utilized for setting the Contour Control function **114**, the Paging Volume function **116**, and the Equalizer Band function **118**.

Reference is next made to FIG. **9**, which shows in more detail the processing steps for the operation of the Octave equalizer module **60** for the control unit **12**. The first step **170** comprises prompting the user to select the desired equalizer band. As described above, the 1/3 Octave Band frequencies comprise 160, 200, 250, 315, 400, 500, 630, 800, 1000, 1250,

1600, 2000, 2500, 3150, 4000, 5000, 6300 and 8000 Hertz (Hz).; and the 1/1 Octave Band frequencies comprise 125, 250, 500,1000, 2000, 4000, and 8000 Hz. Next in block **172**, the band menu for the selected band is displayed, and the user is prompted to enter the setting for the band. The control unit **12** then prompts the user to select the next equalizer band in block **174**.

Reference is next made to FIG. **10**, which shows the operation of the timer functional module **68** and menu in more detail. The first step **180** as shown in FIG. **8** comprises prompting the user to select one of the master sound masking units **14** for setting the timer function. In response to the user's action, the control unit **12** displays the Weekday/Time/Level setting for the selected unit **14**, and the user is prompted to change the setting. If the user changes the setting in step **184**, then the new setting is stored by the control unit **12** and also applied to the selected sound masking unit **14**.

Reference is next made to FIG. **11**, which shows the operation of the diagnostic functional module **72** and menu for the control unit **12** in more detail. The first step **190** involves prompting the user to select one of the master sound masking units **14** for the diagnostic test. In response, the control unit **12** retrieves the serial number from the master sound masking unit **14** over the network **13** as indicated by block **192**. If there is an error (as indicated by decision block **194**), then a communication error **196** is logged for that unit **14** and another unit **14** is selected **210**. If there is no communication error (decision block **194**), then the control unit **12** checks the serial number against the entry stored in a lookup table in block **198**. If the serial number does not match the entry in the lookup table, then an identification error is logged in block **202**, and another master sound masking unit **14** is selected in block **210**. If the serial number matches the entry in the lookup table (decision block **200**), then the status for the master sound masking unit **14** is queried by the control unit **12** in block **204**. The status of the selected master sound masking unit **14** is checked in block **206**, and if the status is fail or does not meet specifications, then a status error is logged in block **208**. The next step in block **210** involves selecting another master sound masking unit **14** and repeating steps **192** through **210**, as described above, until all, or the selected group, of the master sound masking units **14** have been queried as determined in block **212**. The last step in the operation of the diagnostic functional module **72** comprises generating and/or displaying a diagnostics report as indicated in block **214**.

Reference is next made to FIG. **12**(*a*), which shows the operation of the system configuration and addressing functional module **70** and menu for the control unit **12** in more detail. The control unit **12** is preferably password protected, and the first step **220** involves prompting the user to enter a password. If the password is incorrect (decision block **222**), then further access is denied (block **224**). If the entered password is correct, the password is displayed in block **226**, and the user is given the option of changing the password (decision block **228**). If the user changes the password, then the new password is saved in block **230**. The next step **232** involves displaying the number of master sound masking **14** that are presently configured for the network **13**. If the system **10** is being setup for the first time, the number of units may be configured at the factory or entered in the field by the technician. The user is given the option of changing the number of units **14** configured for the system **10** in decision block **234**, and the new number of units **14** is stored in step **236**.

Referring still to FIG. **12**(*a*), in decision block **238**, the user is prompted to initialize the system **10**. If the user elects to initialize the system **10**, then the control unit **12** executes an initialization procedure indicated generally by reference **240**.

The initialization procedure **240** is shown in more detail in FIG. **12**(*b*). As shown, the first step **241** in the initialization procedure **240** involves resetting all of the master sound masking units **14** connected to the network **13**. As a result of the reset operation **241**, each of the master sound masking units **14** has a logical address of 0. Since all of the units **14** have logical address 0, the first sound masking unit **14**, i.e. unit **14***a*, responds when the control unit **12** queries the units **14** as indicated by block **242**. The selected unit **14** is then queried for its serial number in block **244**. The serial number **244** is assigned to the unit **14** at the time of manufacture and preferably comprises a code stored in non-volatile memory in the unit **14**. The serial number may be rewritten by the control unit **12** as described in more detail below. The control unit **12** uses the serial number to generate a unit address, i.e. logical address, for the unit **14** as indicated in block **246**. The serial number is preferably stored in memory, for example a look-up table in the control unit **12**, and provides a cross-reference to the master sound masking unit **14**. The current logical address generated in step **246** is unique for the unit **14** in the present network configuration **10**, but for another network configuration the logical addresses may be regenerated. Following the addressing operation, the next sound masking unit **14** is selected by the control unit **12** and the current logical address is incremented for the next sound masking unit **14**. The operations for assigning the current logical address to the unit **14** based on the serial number according to steps **244** to **248** are repeated. These operations are repeated until all of the sound masking units **14** have been assigned current logical addresses by the control unit **12** as indicated by decision block **250**. Following this scheme, the current logical address for the last sound masking unit **14** is equal to the number of sound masking units **14** connected to the networked system **10**.

Reference is next made to FIG. **13**, which shows the timer function **106** (FIG. **5**) in more detail. In response to an interrupt or a request from a polling loop, a wake-up call or "clock tick" is periodically issued as indicated in step **260**, and a schedule of timed events is checked in block **262**. The timed events may comprise, for example, changes in the level of the sound masking signal for all or some the master sound masking units **14** (and the associated satellite sound masking units **16**). If the schedule indicates that there is no change in sound masking level, then the timer function **106** goes to sleep (block **266**). If there is a scheduled change, then the new level for the sound masking signal is transmitted via the network **13** to the affected sound masking units **14** (block **268**).

Reference is next made to FIG. **14**, which shows in flowchart form the control structure **300** for controlling the master sound masking units **14**. As shown, the control structure **300** includes an initialization procedure **301**, a program serial number procedure **302**, a read serial number procedure **303**, an assign logical address procedure **304**, a read sound masking signal level procedure **305**, and a write sound masking signal level procedure **306**.

The initialization procedure **301** comprises a function **304** for resetting the logical addresses and a function **306** for generating and writing logical addresses for the units **14** as described above with reference to FIG. **12**. The program serial number procedure **302** provides a mechanism for programming or regenerating the serial number stored in non-volatile memory for each unit **14**. The procedure **302** comprises a write serial number function **312**. The read serial number procedure **303** comprises a read serial number function **314** which the control unit **14** utilizes to read the serial numbers of the units **14**, for example, as described above with reference to FIG. **12**. The assign logical address procedure **304** comprises a write address function **316** for writing, i.e.

assigning, logical addresses to the sound masking units **14**. The read level procedure **305** comprises a read level function **318** which allows the control unit **12** to read the current level setting for the sound masking signal in the unit **14** being addressed by the control unit **14** or the remote control unit. The write level procedure **306** comprises a write level function **320** which allows the control unit **12** (or remote control unit) to write, i.e. set, the level setting for the sound masking signal in the unit **14** being addressed by the control unit **14** or the remote control unit. Once the unit **14** is selected, the control unit **12** next selects the function to be queried/programmed, and then reads the parameter setting from the digital control device **33** to **37** (e.g. the digi-pot for the filter stage **32** in FIG. **2**) using the read level function **318**, or writes the parameter setting to the digital control device **33** to **37** (e.g. the digi-pot the audio power amplifier stage **36** in FIG. **2**), using the write level function **320**.

As described above with reference to FIG. **1**, the remote control unit **18** works in conjunction with the control unit **12** to display and/or adjust the current adjustment settings (i.e. spectrum adjustment settings, equalizer settings, masking signal volume level, and paging volume) for the master units **14**. The remote control unit **18** is operated through menu functions as shown in FIG. **15**. Referring to FIG. **15**, the function menus for the remote control unit **18** comprise a gain control menu **350**, a contour control menu **352**, a paging control menu **354**, and an equalizer control menu **356**. The user uses these menus to program (i.e. write) and read the gain, contour, and paging functions as described above for the control unit **12**.

As described above, the sound masking units **14** according to the present invention include an equalizer stage **34** which allows the shaping of the sound spectrum of the sound masking noise signal output. Advantageously, the capability to address each of the sound masking units **14** allows the equalizer stage **34** to be individually set for each of the units **14** or a group of the units **14**, and this capability greatly enhances the functionality of the networked sound masking system **10** according to the present invention.

Reference is made to FIG. **16** which shows a procedure **400** according to another aspect of the invention for controlling the equalizer function in each of the sound masking units **14**. According to this aspect, the remote control unit **18** (FIG. **1**) includes a serial communication interface **21** (e.g. radio or hard-wire link) which couples to a sound level meter **23** (FIG. **1**), such as the RION NA-27 meter. The sound level meter **23** is used to take sound level readings for the physical space and these readings are transmitted to the remote control unit **18** via the serial communication interface **21**. As will now be described with reference to FIG. **16**, the readings from the sound level meter **23** are used in conjunction with settings in a Prescribed Contour Table stored in the control unit **12** or the remote control unit **18** to adjust the level settings in the equalizer stages **34** for the sound masking units **14**.

As shown in FIG. **16**, the first operation in the equalization procedure **400** comprises selecting a 1/1 Octave analysis ora 1/3 Octave analysis as indicated in block **402**. The next operation involves selecting between an automatic mode of operation or a manual mode of operation as indicated in block **404**. Once the mode of operation is selected, the user (i.e. technician) enters the unit ID to address the sound masking unit **14** on which the equalizer function is to be adjusted/programmed (block **406**). Once the unit **14** is addressed, the remote unit **18** queries the unit **14** for the first sound level setting $L_o$ for the first frequency band $f_o$ as indicated in block **408**.

Referring still to FIG. **16**, if the automatic mode of operation is selected (block **404**), then the sound level meter **23** reads the level setting L from the unit **14** (block **410**) and the level setting L is compared to a minimum level setting $L_{min}$ in block **412** and a maximum level setting $L_{max}$ in block **414**. The minimum $L_{min}$ and maximum $L_{max}$ level settings are determined from a Prescribed Contour Table 500 (block **416**) such as depicted in FIG. **17**. If the level setting L is not greater than the minimum level setting $L_{min}$, then the remote unit **18** sends a command or message to the control unit **12** to increase the level setting L for the equalizer by one step, as indicated in block **418**. If the level setting L is greater than the minimum level setting $L_{min}$, then the level setting L is compared to the maximum level setting $L_{max}$ in decision block **414**. If the level setting L is not less than the maximum level setting $L_{max}$, then the remote unit **18** transmits a message to the control unit **12** to decrease the level setting L for the equalizer by one step as indicated in block **420**. The control unit **12** makes the adjustment to the equalizer setting for the addressed unit **14**, and sends a confirmation message to the remote unit **18**. The remote unit **18** then accepts a new reading from the sound level meter **23** and the remote unit **18** reads the level setting L in block **410** and the steps in blocks **412**, **418**, **420** are repeated until the level setting L is set within the desired range $L_{min}$ to $L_{max}$ as defined by the Prescribed Contour Table 500 (FIG. **17**). For example, the Prescribed Contour Table 500 includes the following level ranges ($L_{min}$, $L_{max}$) for the center frequencies in the 1/1 Octave band or 1/3 Octave band:

| ($L_{min}$, $L_{max}$) | Center Frequency |
|---|---|
| 48 dB, 56 dB | $F_0$ = 160 Hz |
| 47.5 dB, 54.5 dB | $F_1$ = 250 Hz |
| . . . | . . . |
| 6.5 dB, 23 dB | $F_{17}$ = 8000 Hz |

Referring back to FIG. **16**, once the level setting L for the current frequency band is set within the range $L_{min}$ to $L_{max}$, the level setting L for the next frequency band is selected as in block **422**, and the remote control unit **18** sends a signal to the sound level meter **23** to read the next level setting L (block **410**).

In the manual mode of operation (as selected in block **404**), the first operation involves using the remote control unit **18** to receive and display a level setting L from the sound level meter **23** as indicated in block **424**. In block **426**, the level setting L is compared to the range $L_{min}$ to $L_{max}$. If the level setting L is not within the prescribed range, the desired level setting L is set or adjusted using the remote control unit **18** as indicated in block **428**. In block **430**, the remote control unit **18** is used to select the next frequency band for reading the next level setting (block **424**).

As described above, the remote control unit **18** in conjunction with a sound level meter **23** provides an effective mechanism for adjusting the equalizer function in each of the sound masking units **14** through the control unit **12** and networked connection without the need for opening the ceiling tile to physically access any of the units **14**.

The present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. Certain adaptations and modifications of the invention will be obvious to those skilled in the art. Therefore, the presently discussed embodiments are considered to be illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed is:

1. A sound masking system for controlling the ambient noise in a physical environment, said sound masking system comprising:

a sound masking command control network in said physical environment;

a plurality of sound masking units including a communication interface for coupling to said sound masking command control network for receiving control signals over said sound masking command control network including a masking volume command and a masking frequency command, at least some of said sound masking units including a sound masking component, said sound masking component being responsive to said control signals for generating a sound masking output signal;

a control unit configured to generate said control signals including said masking volume command and said masking frequency command, and said control unit having a communication interface for coupling to said sound masking command control network for transmitting said control signals to selectively control operation of said plurality of sound masking units.

2. The sound masking system as claimed in claim 1, wherein said sound masking unit includes an address component for recognizing control signals intended for the sound masking unit associated with said address component.

3. The sound masking system as claimed in claim 2, wherein said control unit includes an address generator for assigning addresses associated with the address component for each of said sound masking units.

4. The sound masking system as claimed in claim 3, wherein said address generator comprises a component for generating a logical address for each of said sound masking units.

5. The sound masking system as claimed in claim 1, wherein said plurality of sound masking units are connected in series in said sound masking command control network.

6. The sound masking system as claimed in claim 5, wherein each of said plurality of sound masking units includes a first interface and a second interface, said first interface interfacing with an upstream side of said sound masking command control network, and said second interface interfacing with a downstream side of said sound masking command control network.

7. The sound masking system as claimed in claim 1, further including a remote unit, and said control unit having a remote communication interface for receiving adjustment signals from said remote unit, and said control unit including a component for converting said adjustment signals into control signals for controlling said sound masking output signal.

8. The sound masking system as claimed in claim 7, wherein said remote unit includes a component for receiving sound measurements and generating said adjustment signals based on said received sound measurements.

9. A sound masking system for controlling the ambient noise in a physical environment, said sound masking system comprising:

a control communication network configured for controlling a plurality of sound masking units in said physical environment;

at least some of said sound masking units including a controller and a communication interface for coupling to said control communication network for receiving control signals over said control communication network, and said controller being responsive to said control signals for generating a sound masking signal and said control signals including a masking volume setting command and a masking frequency setting command;

a control unit configured to generate said control signals including said masking control setting command and said masking frequency setting command, and said control unit having a communication interface for coupling to said communication network for sending said control signals to selectively control operation of said plurality of sound masking units.

10. The sound masking system as claimed in claim 9, wherein said sound masking unit includes a communication interface for transmitting one or more signals to said control unit over said control communication network.

11. The sound masking system as claimed in claim 10, wherein said sound masking unit includes an address component for recognizing control signals intended for the sound masking unit associated with said address component.

12. A sound masking system for controlling the ambient noise in a physical environment, said sound masking system comprising: a sound masking control communication network in said physical environment; a plurality of sound masking units, at least some of said sound masking units including a controller having a component for generating a sound masking output signal and a communication interface for coupling to said sound masking control communication network for receiving and transmitting control information over said sound masking control communication network, and said control information including address information identifying one or more of said sound masking units, and said controller being responsive to said control information addressed to said associated sound masking unit for controlling said sound masking output signal; and a control unit configured to generate said control information including said address information, and said control unit having a communication interface for coupling to said sound masking control communication network for transmitting said control information to selectively control operation of said plurality of sound masking units, wherein said control information includes a sound masking volume command and a sound masking frequency command.

13. A method for selectively controlling a plurality of sound masking units, said method comprising the steps of:

configuring said plurality of sound masking units in a sound masking control communication network so as to have an interface for receiving a plurality of control commands over said sound masking control communication network to selectively control operation of said plurality of sound masking units;

generating said plurality of control commands; monitoring said sound masking control communication network and said plurality of control commands and receiving one of said plurality of control commands addressed to one of said sound masking units;

interpreting said received control command; and

generating a sound masking signal having one or more characteristics based on said interpreted control command,

wherein said interpreted command comprises a sound masking volume setting command and a sound masking frequency setting command.

14. The method as claimed in claim 12, further including the step of configuring a plurality of said sound masking units into one or more zones, and controlling said sound masking units for said corresponding sound masking zones to generate sound masking signal outputs independently of said other sound masking zones.

15. The method as claimed in claim 14, wherein said step of controlling comprises transmitting said sound masking volume and said sound masking frequency setting commands to said plurality of sound masking units associated with each of said sound masking zones using address information.

16. A networkable sound masking device comprising:

a communication interface for interfacing to a sound masking device control network for transmitting control signals to selectively control operation of said networkable sound masking device;

a controller for receiving said control signals from said interface, said control signals being intended for the networkable sound masking device and said control signals comprising a masking volume command and a masking frequency command;

a sound masking component for generating a sound masking output signal, said sound masking component being responsive to said controller, and said sound masking output signal being responsive to said masking volume command and said masking frequency command;

an output stage for outputting said sound masking signal.

17. The networkable sound masking device as claimed in claim 16, wherein said interface includes an address component for recognizing said control signals intended for the networkable sound masking device.

18. The networkable sound masking device as claimed in claim 16, wherein said output stage comprises an amplifier and said controller including a component for controlling said output stage in response to said masking volume setting signal.

19. The networkable sound masking device as claimed in claim 16, wherein said sound masking component comprises a random noise generator having an output coupled to an equalizer stage, and said controller including a component for controlling said equalizer stage in response to said masking frequency setting signal.

20. The networkable sound masking device as claimed in claim 19, wherein said output stage comprises an amplifier and said controller including a component for controlling said output stage in response to said masking volume setting signal.

21. A sound masking system for controlling the ambient noise in a physical environment, said sound masking system comprising:

a communication network configured for controlling sound masking in said physical environment;

a plurality of sound masking units, at least some of said sound masking units including a sound masking generator and a communication interface for coupling to said communication network configured for controlling sound masking and configured for receiving control signals over said communication network including a masking volume setting signal and a masking frequency setting signal, and said sound masking generator being responsive to said masking volume setting signal and said sound masking frequency setting signal for generating a sound masking output signal;

a control unit configured to generate said control signals including said masking volume setting signal and said masking frequency setting signal, and said control unit having a communication interface for coupling to said communication network for transmitting said control signals to selectively control operation of said plurality of sound masking units;

a plurality of zones, and one or more of said sound masking units being associated with one or more of said zones.

22. A sound masking system for masking sound in a physical environment, said sound masking system comprising:

a sound masking control communication network for said physical environment;

a plurality of sound masking units, at least some of said sound masking units including a sound masking generator and a communication interface for coupling to said sound masking control communication network for receiving a plurality of control signals over said sound masking control communication network including a masking volume control command and a masking frequency control command, and said sound masking generator being responsive to said masking volume control command and said sound masking frequency control command for generating a sound masking output signal, said sound masking output signal having a volume derived from said masking volume control command and a frequency characteristic derived from said sound masking frequency control command;

a control unit configured to generate said control signals including said masking volume control command and said masking frequency control command, and said control unit having a communication interface for coupling to said communication network for transmitting said control signals to selectively control operation of said plurality of sound masking units.

23. The sound masking system as claimed in claim 22, wherein said sound masking unit includes an address component for recognizing control signals intended for the sound masking unit associated with said address component.

24. The sound masking system as claimed in claim 22, wherein said plurality of sound masking units are associated with a plurality of sound masking zones, each of said sound masking units being associated with one of said plurality of sound masking zones, and said sound masking units providing sound masking for said associated sound masking zone independently of said other sound masking zones.

25. The sound masking system as claimed in claim 24, wherein said sound masking units associated with each of said sound masking zones provide a sound masking output tailored for said associated sound masking zone and said sound masking output being based on said masking volume and said masking frequency control commands.

26. The sound masking system as claimed in claim 22, further comprising a plurality of zones, and one or more of said sound masking units being associated with one or more of said zones.

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